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(54) Projection imaging

(57) An image is projected from a mask 4 on to a wafer 5 using a light source 7 to form a semiconductor device by photo-lithography. Sensor(s) 22 are provided near mask 4 for monitoring the luminosity and light distribution in the optical path between light source 7 and mask 4. The output of sensor(s) 22 is fed to a detector 23 which activates an alarm 24 when the luminosity or light distribution depart from predeterminal values, or activates compensation means e.g. one or more light shields 26 (Figs. 3 and 6—not shown) which varies the distribution of light from the lamp 7. This prevents incorrect exposure of the wafer 5, which would result in a defective semiconductor device.

FIG. 1

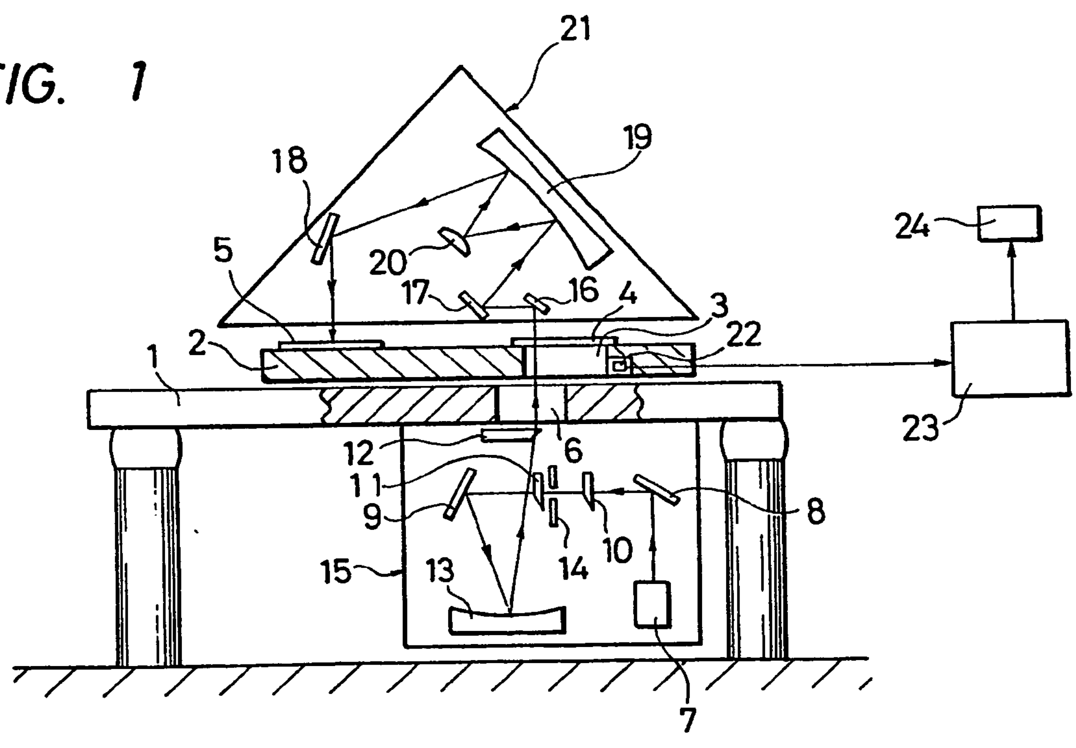

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FIG. 1

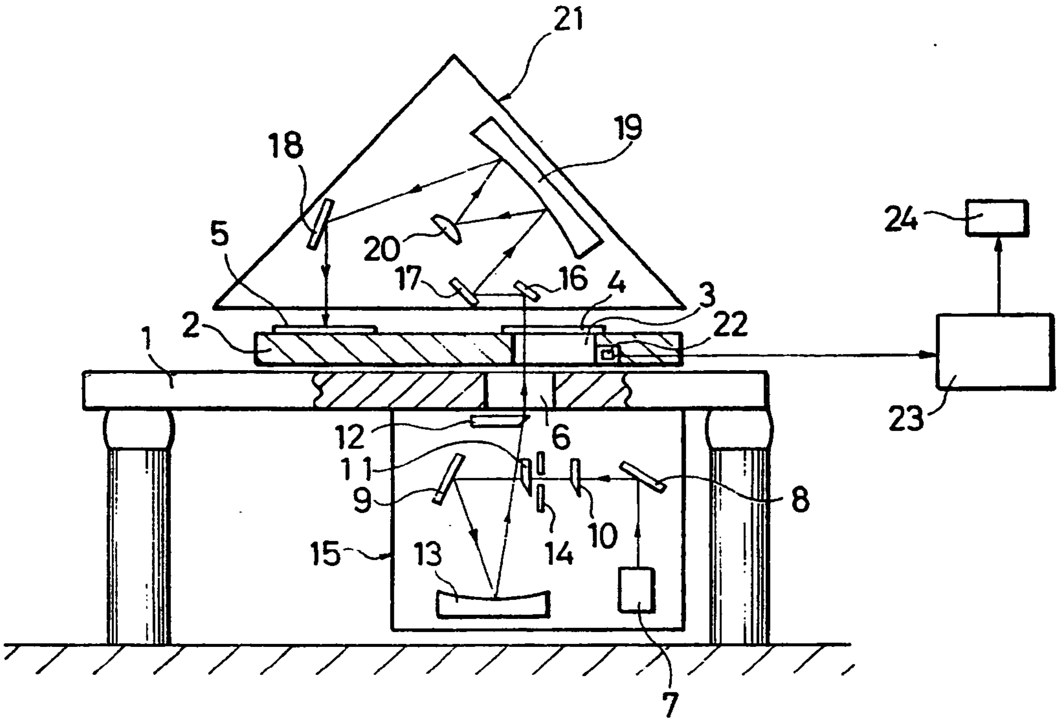


FIG. 2

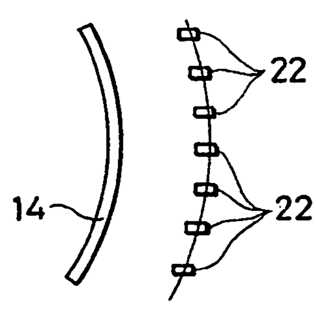
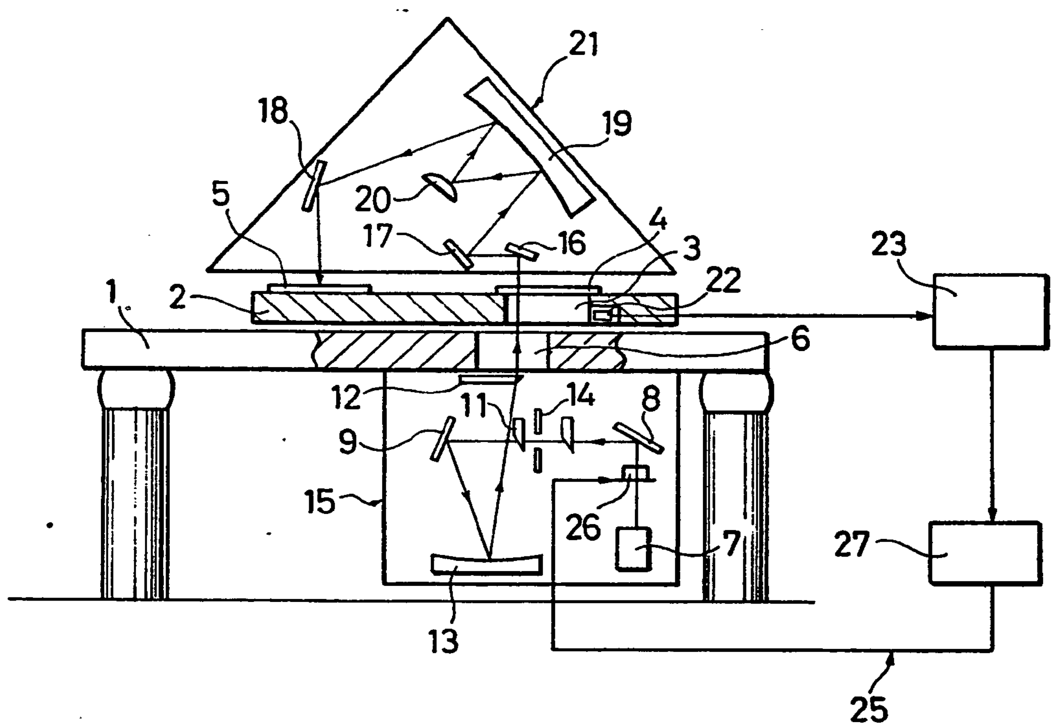


FIG. 3



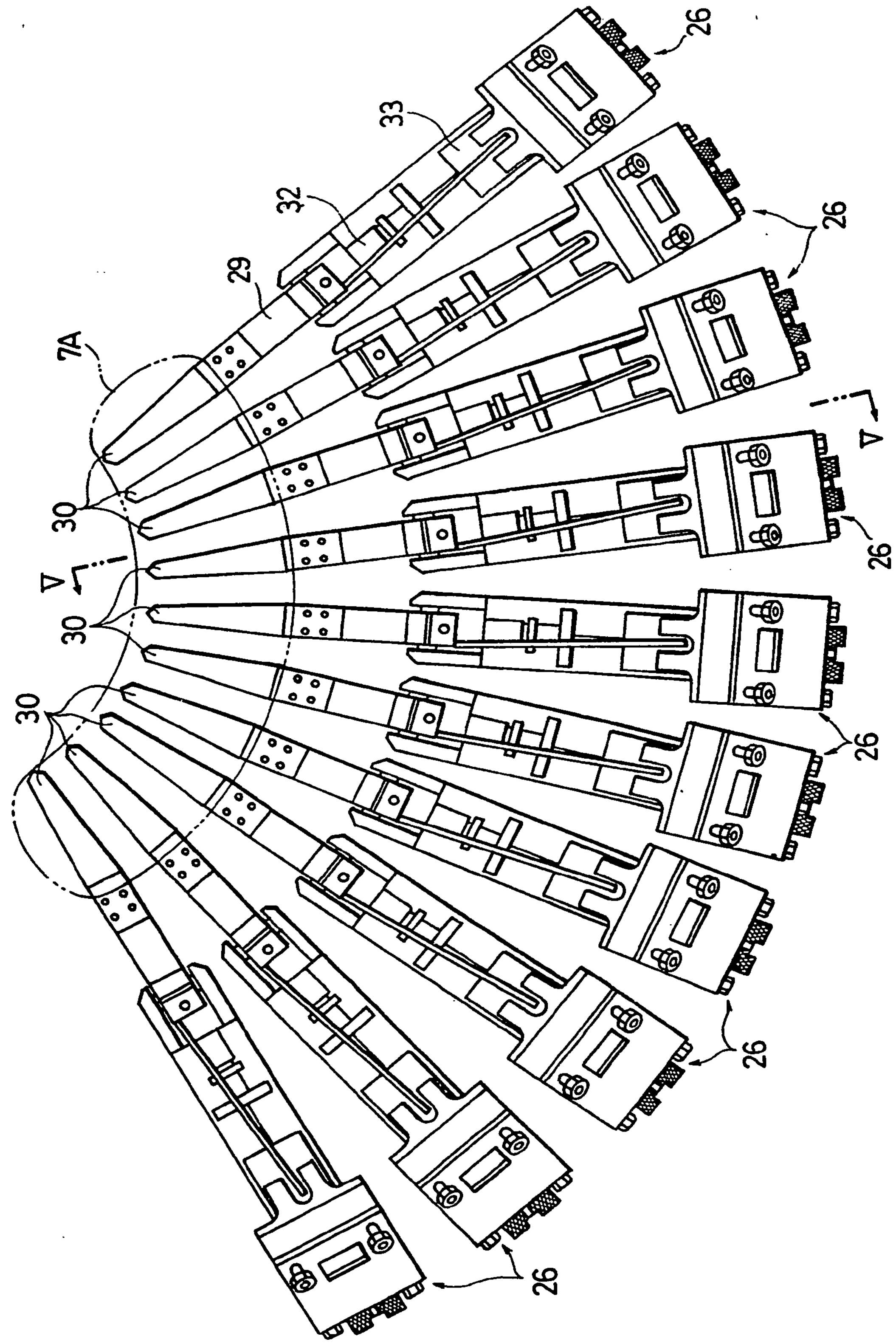


FIG. 4

FIG. 5

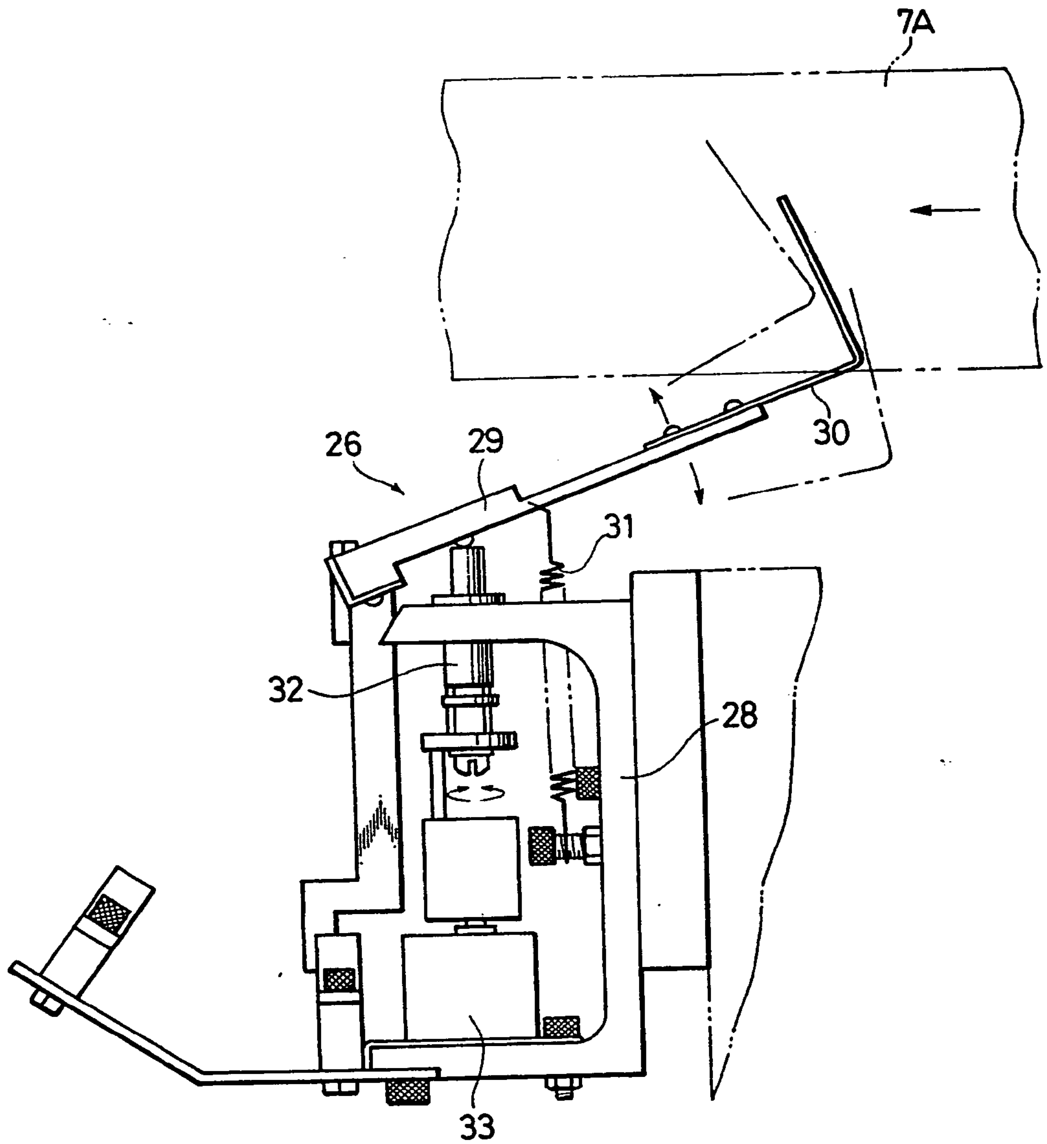
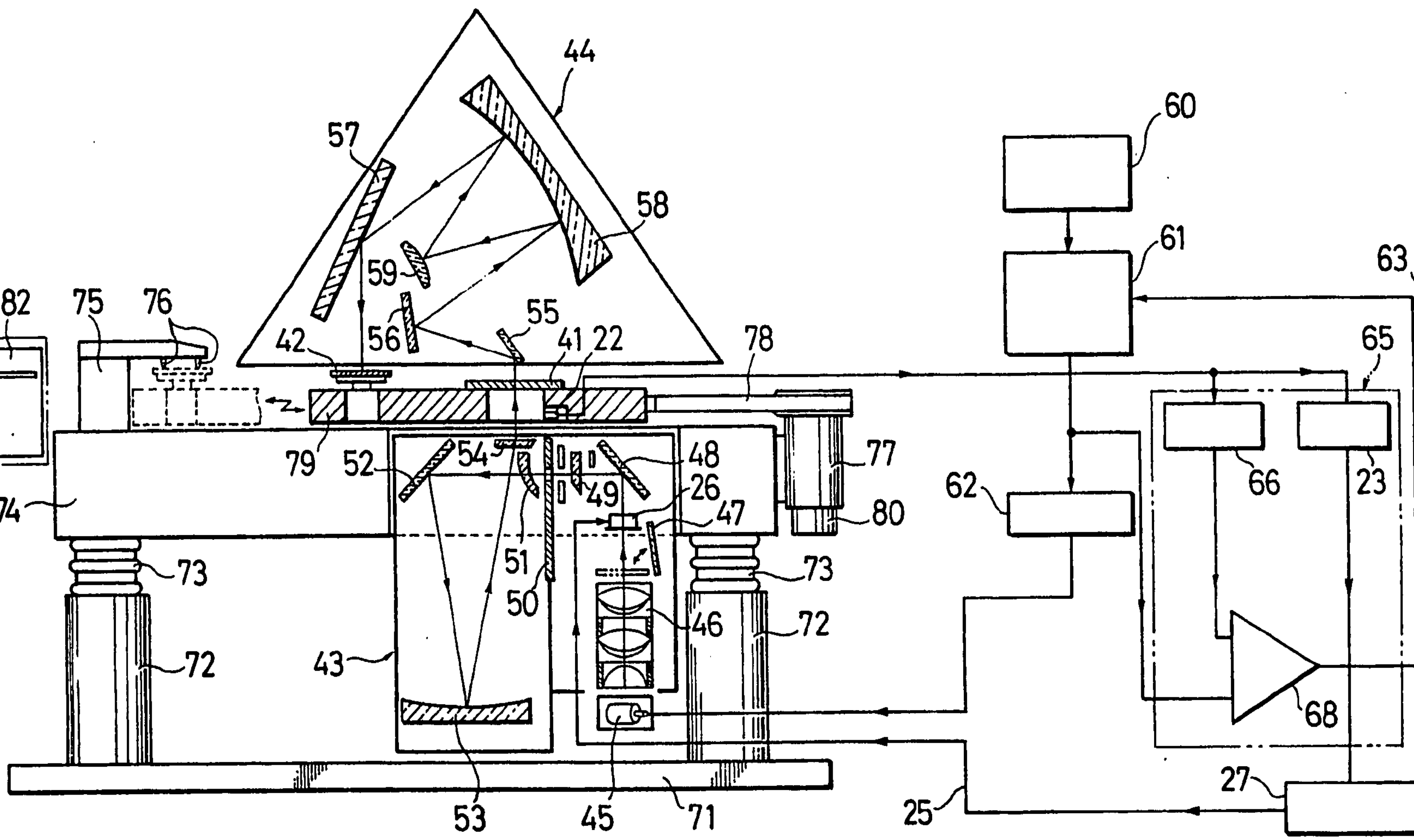


FIG. 6



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SPECIFICATION

Projecti n aligner

The present invention relates to a proj ction aligner.

It is common to form an integrated circuit on a semiconductor wafer by means of a photolithographic process in which a photoresist film on the wafer surface is exposed to a pattern of light and then the wafer is etched. It is possible to use a contact-type process in which a photo-mask is held in close contact with the wafer and the wafer is exposed to light through the photo-mask. A more versatile process, however, is to use a projection aligner to form an image of the pattern of the photo-mask and project that image onto the wafer using an optical system. A disadvantage of such a process is that nonuniformity in the luminosity of the illuminating light and nonuniformity in the distribution of the light are prone to occur directly affecting the image of the mask pattern on the wafer. To form a pattern image of the correct luminosity light distribution, it is therefore necessary to control strictly the luminosity of the illuminating light and the distribution thereof.

The known method of achieving this is for the operator of the projection aligner to measure the luminosity and distribution of light at parts of the projection aligner near the wafer and adjust the various parts of the aligner on the basis of the measured results so as to make the luminosity and distribution uniform. Therefore, when the luminosity or the light distribution deviates from the desired values during operation or during any other preparatory operation, it is difficult to find out what deviation has occurred. Deviation results in the photoresist film being exposed to light of improper luminosity or light distribution, and the exposed dimensions do not fall within the operating tolerances, thereby producing a defective article. The manufacturing process therefore has a lower available percentage, being the percentage of articles produced which operate satisfactorily.

Therefore the present invention proposes providing at least one sensor in the optical path between the light source and the wafer for monitoring the luminosity (and preferably also the distribution) of the light. It would be possible to position the sensor(s) so that they detect the light actually projected onto the wafer. However, in such an arrangement, the sensor(s) would be shaded by the photo-mask and the sensor(s) in turn shade the wafer. Therefore it is preferable that the sensor(s) monitor the light in the part of the optical path between the light source and the mask.

The sensor(s) may be arranged near the light source or near a reflector on the optical system which illuminates the mask. Such a position, however, makes it difficult or impossible to d termine precis ly the quantity of light which reaches the wafer after passing through a large number of additional optical elements, based on a measurement taken near the light source. A further disadvantage of having the sensor(s) near the lamp is that a complicated structure is necessary for eliminating the influences of e.g. lamp heat.

Therefore it is preferable that the sensor(s) are located closely proximate the mask, for example, on a mask holder supporting the mask in the projection aligner. The sensor(s) may be movable into and out of the optical path.

The output of the sensor(s) may be fed to detection means which detects the luminosity and distribution of the light. The detection means may trigger an alarm if the luminosity or distribution varies from a predetermined luminosity or distribution and/or may activate compensation means for changing the distribution of light in the optical path.

The present invention permits the construction of a projection aligner which can promptly detect deviations in a luminosity and the distribution thereof so as to prevent the formation of defective articles; by compensating immediately and automatically for incorrect luminosity and the nonuniform light distribution.

Control of the quantity of light from a lamp forming the light source enables the luminosity and the distribution of light on the wafer to be stabilized to permit accurate wafer fabrication and the formation of a semiconductor device of high quality, and the apparatus can be rendered simple in structure and low in cost.

Embodiments of the present invention will now be described in detail, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a front view showing the projection aligner which is a first embodiment of the present invention;

Figure 2 is an explanatory view showing the arrangement of luminosity sensors;

Figure 3 is a front view showing a projection aligner which is a second embodiment of the present invention;

Figure 4 is a front view of light shield devices;

Figure 5 is a side view of the light shield device taken along line V—V in Figure 4; and

Figure 6 is a front view showing a projection aligner which is a third embodiment of the present invention.

Referring first to Figure 1, which shows a first embodiment of the present invention, being a 1:1 projection aligner, a scan table 2 is reciprocatable rightwards and leftwards as viewed in Figure 1 on a bed 1 by means of an air bearing mechanism (not shown). A photo-mask 4 having a predetermined pattern formed on it is set on a through hole 3 which is provided at one end of the scan table 2. A semiconductor wafer 5 whose surface is coated with a photoresist is set at the other nd of the scan table 2. The bed 1 has a through hole 6 at one end thereof. Under this hole 6 is an illumination unit 15 which has a lamp 7 forming a light source, reflectors 8, 9, lenses 10, 11, 12, a concave mirror 13 and a slit member 14.

The illumination unit 15 transmits the light from the lamp 7 through the lenses 10 to 12 and the slit via the reflectors 8, 9, the light then passes through the hole 6 in the bed 1. When the holes 3, 6 in the scan table 2 and bed 1 respectively are aligned, a band of light formed by the arcuate slit of the slit member 14 illuminates the photo-mask 4. A focusing unit 21 which has reflectors 16, 17, 18, a concave mirror 19 and a convex mirror 20 is provided above the through hole 6, the focusing unit projecting and focusing the image of the photo-mask 4 on the surface of the wafer 5.

A plurality of luminosity sensors 22 are provided in the through hole 3 of the scan table 2 and are fixed arcuately so as to conform to the shape of the slit as shown in plan view in Figure 2. The luminosity sensors 22 are connected to detection means 23 which preferably includes a microcomputer, and in which the outputs of the respective luminosity sensors 22 are compared with one another and with a predetermined reference value. An alarm unit 24 is connected to the detection means 23, and is actuated by a predetermined output signal from the latter.

According to the above construction, the arcuate band of light formed in the illumination unit 15 illuminates the photo-mask 4 through holes 6 and 3 respectively. The illuminated part of the photomask is focused on the surface of the wafer 5 by the focusing unit 21. Accordingly, when the scan table 2 is moved, for example, leftwards as viewed in Figure 1, the band of light scans the whole surface of the photo-mask 4, with the result that the wafer surface is exposed to light from every part of the photo-mask. When the scan table 2 is moved a distance which is somewhat greater than the dimension of the photo-mask 4, the band of light impinges on the plurality of luminosity sensors 22 disposed in close proximity to the photo-mask 4, and the luminosities of corresponding parts of the band of light may be derived from the respective luminosity sensors 22. Accordingly, the detection means 23 detects the luminosity of the band of light and the distribution of the light in that band on the basis of the outputs of the sensors. When the luminosity and the light distribution deviate from predetermined values, the detection means 23 actuates the alarm unit 24, and the operation of the projection aligner is stopped by an operator or automatically.

Thus, with the projection aligner of the first embodiment, the luminosity and the distribution of light are checked at each reciprocation of the scan table 2, which corresponds to a check at each exposure of the photo-mask 4, and the exposure is stopped immediately deviations in the luminosity and the distribution of light are detected so that a defective article caused by nonuniformity in the exp sure luminosity can reliably b prevented, and the available percentage can be improved. Moreover, the use of a projection aligner according t the present invention permits the luminosity monitoring and light distribution monitoring, performed in a pr paratory operation once a day to be omitted and may shorten the period of time of the preparatory operation.

Instead of having a plurality of luminosity sensors 22, it is possible to move a single luminosity sensor arcuately along the band of light and to measure luminosities at respective points during the movement of the sensor.

Figure 3 shows a second embodiment of a projection aligner according to the present invention. Parts corresponding to those in Figure 1 have the same reference numerals and will not be explained in detail.

The second embodiment has compensation means 25 for automatically compensating the luminosity and the light distribution on the basis of the output from the detection means 23. Referring to Figure 3, light shield devices 26 are disposed within the illumination unit 15, and they are driven by a control unit 27 which operates on the basis of the output of the detection means 23, whereby the luminosity and the light distribution may be compensated.

As shown in Figures 4 and 5, the plurality of light shield devices 26 are juxtaposed along the arcuate band of light 7A from the light source lamp 7. Each light shield device 26 is driven independently of the others and each has a rocking arm 29 one end of which is supported at the upper end of a frame 28, and the other end of which has a substantially L-shaped light shield plate 30 fixed thereto. The arm 29 is urged downwards by a tension spring 31, while the fore end of a micrometer head 32 supported by the frame 28 abuts on the lower surface of the arm. The micrometer head 32 is coupled to a pulse motor 33 mounted on the bottom of the frame 28 so that the fore end of the micrometer head 32 is moved up or down in accordance with the direction of rotation of the motor. This pulse motor 33 is driven to rotate forwards or in reverse by a signal from the control unit 27 which is connected to the detection means 23.

When the detection means 23 detect nonuniformity in the luminosity or light distribution on the basis of the outputs of the luminosity sensors 22, it informs the control unit 27 which parts of the band of light have a higher luminosity or a lower luminosity. In response thereto, the control unit 27 selectively drives the light shield devices 26 which correspond to the part of the band of light requiring compensation. The micrometer head 32 of each light shield device 26 at a part of higher luminosity is rotated by means of the pulse motor 33 to move the fore end of the micrometer head up and to rock the arm 29 upwards. Thus, the light shield plate 30 attached to the arm 29 is moved into the light beam 7A, to reduce the quantity of light in the corresponding part of the band of light and to lower partially the luminosity. For a part of the band of light with power luminosity, the pulse motor rotates to move the light shield plate 30 down and withdraw it from the light beam 7A, to increase the quantity of light to the corresponding part of the band of light and to raise th luminosity. Accordingly, uniform luminosity may

be achieved automatically by controlling the respective light shield devices 26 independently of each ther.

The light shield devices 26 may be replaced with another construction, and it is required only that the amount the light shield plate advances into or is withdrawn from the light beam can be adjusted. Alternatively the apparatus may have compensation means in which the position of the lamp forming the light source may be varied, instead of having light shield devices, so as to render the light distribution uniform by adjusting the position of the lamp.

Thus according to the projection aligner of the present invention, at least one sensor is located in the optical path, preferably at each exposure of a photo-mask, for detecting the luminosity and preferably the light distribution in the optical path. When the distribution has become nonuniform, the nonuniformity may be automatically compensated for. Therefore, the luminosity and the distribution of light may always be held at correct and uniform values, and a defective article caused by improper luminosity or nonuniform luminosity does not occur, enhancing the available percentage.

Figure 6 is a diagram of a projection aligner which is a third embodiment of the present invention. A mask 41 is formed with a predetermined pattern, and the mask pattern is printed onto a wafer 42 through exposure to light. The mask 41 is illuminated by an illuminating optical system 43, and the mask pattern is focused on the surface of the wafer by a focusing optical system 44. The illuminating optical system 43 is constructed so that light emitted from a lamp 45 is passed through a condenser lens 46 to magnify the image of the lamp 45 and then through an ultraviolet radiation elimination filter 47 and an infra-red radiation elimination filter (cold mirror) 48 to be converged on a slit 50 following a lens 49. Light which has passed through the slit 50 is focused as a band of light on the mask 41 by a lens 51, plane mirror 52, concave mirror 53 and lens 54, and the band of light scans the mask 41 with the movement of this mask 41. The focusing optical system 44 is constructed so that the mask pattern can be focused on the surface of the wafer 42 by plane mirrors 55, 56, 57, a concave mirror 58 and a convex mirror 59. A power source unit for the lamp 45 has a power supply 60, a controller 61 which includes a sliding voltage regulator or an SCR (Silicon Controlled Rectifier) for varying and controlling the supply voltage of the power supply 60 within a range not higher than a fixed voltage (e.g. 200 V), and a transformer 62 which receives the output voltage of the controller 61 as its primary voltage and boosts it to a secondary voltage of high voltage.

A luminosity control unit 63 has luminosity monitoring sensors 22 disposed at positions closely proximate the mask 41, and the luminosity signals from the sensors to a microcomputer 65 forming a detection means. The sensors 22 may be similar to those shown in Figure 2. The detection signal is processed in the microcomputer 65, to a set value by a processor 66, and the set value is applied to one input terminal of a comparator 68. The other input terminal of the comparator 68 receives the primary voltage delivered from the controller 61. By using the output of the comparator 68, the degree of variation in voltage of the controller 61 is controlled to change the primary and secondary voltages, whereby the luminosity of the lamp 45, and hence the quantity of light to the mask, may be adjusted.

In Figure 6, a base 71 supports, via a strut 72 and an air spring 73, a granite surface table 74. Also provided is a wafer focusing unit 75 having leveling pads 76. A servomotor 77 drives a scan table 79 by the use of a metal belt 78, the servomotor being additionally provided with a tachometer generator 80. A loader/unloader 81 for the wafer, a custody portion 82 which has the custody of a large number of cartridges for receiving the wafers are also shown in Figure 6.

In the projection aligner of the third embodiment, as described before, a plurality of luminosity monitoring sensors 22, which may be as illustrated in plan in Figure 2, are disposed and fixed arcuately so as to conform to the shape of the slit 50. The respective sensors 22 are connected, not only to the processor 66, but also to detection means 23 in the luminosity control unit 63. The detection means 23 compares the outputs of the respective sensors 22 with one another and with a predetermined reference value. Compensation means are provided for automatically compensating the luminosity distribution on the basis of outputs from the detection means 23 which determine the luminosity distribution, the compensation means being formed by light shield devices 26 as shown in Figures 4 and 5 disposed within the illuminating portion 43. The light shield devices are driven by a control unit 27 which operates on the basis of the outputs of the detection means 23, whereby the errors in the luminosity distribution can be compensated.

In this construction, the illuminating optical system 43 formed by the condenser lens 46, slit 50, concave mirror 53 etc. focuses a band of light from the lamp 45 on the mask 41, to form the mask pattern as a new light source. The focusing optical system 44 focuses the image of the mask pattern on the wafer 42 by means of the mirrors 55, 56, 57, 58 and 59, to project the image of the mask pattern on the wafer for exposure to light. Each of the luminosity monitoring sensors 22 detects the luminosity of the light at a position very close to the side of the mask 41 nearest the lamp, and the detected value is processed by the processor 66 to a value which is inputted to the comparator 68. Simultaneously, the primary voltage outputted from the controller 61 is inputted to the comparator 68. Each time the signals from the luminosity monitoring s nsors 22 are applied to the luminosity control unit 63 (in

other words, at each scanning of the mask 41 by the light from the lamp), the optimum value is determined, and the degr e of voltage variation of the controller 61 is controlled in accordance with such intermittently-variable value. Thus, the primary and secondary voltages are correctly varied and controlled, and the luminosity of the lamp 45 is feedback-controlled so that the intensity of illumination at the mask 41 may be held constant.

Furthermore, according to the construction of the third embodiment of the present invention, when the luminosity detection means 23 has detected nonuniformity in the luminosity on the basis of the outputs of the luminosity sensors 22, it informs the control unit 27 of a higher luminosity part or lower luminosity part of the band of light. In response thereto, the control unit 27 selectively drives one or more of the light shield devices 26 which correspond to the part of the band of light requiring compensation. More specifically, a light shield device 26 at a part of the band of light having higher luminosity rotates the micrometer head by means of a pulse motor, thereby to move the fore end of the micrometer head up and to rock an arm upwards. Thus, a light shield plate attached to the arm is moved into the light beam, to reduce the quantity of light of the corresponding part and to lower the luminosity. For a part of the beam of light having lower luminosity the pulse motor rotates to move the light shield plate down so that it is withdrawn from the light beam, to increase the quantity of light of the corresponding part of the band of light and to raise the luminosity. Accordingly, uniform luminosity may be achieved automatically by controlling the respective light shield devices 26 independently of one another.

Thus light having passed through optical elements such as lenses (which have a great influence on fluctuations in luminosity) is detected and monitored and the ensuing light is projected on the wafer by mirrors (which have less influence on fluctuations in luminosity), so that a luminosity value differing only by a small amount from the luminosity on the wafer can be detected and monitored. In this way the fluctuations of luminosity at the wafer can be made very small. Moreover, in the embodiments illustrated the monitoring sensors 22 are disposed at positions where the band of light from the lamp is focused, so that the luminosity for the total quantity of light from the lamp can be detected, and the accuracy of the control can be further enhanced.

Furthermore, in the third embodiment, the primary voltage of the power source portion unit is utilized for detecting the light quantity control signal of the lamp. Therefore, the structure of the whole apparatus is simplified, and comparison and control can be carried out at all times. It is also possible to alter the set value nly intermittently. Accordingly, the present invention is applicable to projection aligners having various constructions.

For example, the signal to the comparator 68 from the lamp may be the secondary power rather than the primary voltage described above, although it is easier to use the primary voltage (which is of low voltage).

The present invention is applicable not only to a 1:1 projection aligner as described, but also to a 10:1 reduction projection aligner, a 5:1 reduction projection aligner, etc.

CLAIMS

1. A projection aligner having a light source adapted to illuminate a patterned mask and an optical system adapted to focus an image of the pattern of the mask on a wafer, including at least one sensor for monitoring the luminosity of light in the optical path between the light source and the wafer.

2. A projection aligner according to claim 1, wherein the sensor(s) monitor the light in the part of the optical path between the light source and the mask.

3. A projection aligner wherein the sensor(s) are movable into and out of the optical path.

4. A projection aligner according to any one of the preceding claims, wherein the sensor(s) are located closely proximate the mask.

5. A projection aligner according to any one of the preceding claims, wherein the sensor(s) are located in a mask holder supporting the mask.

6. A projection aligner according to any one of the preceding claims, wherein a source signal derived from the supply voltage to the light source is compared with the output of the sensor(s), thereby to derive a signal for controlling the quantity of light generated by the light source.

7. A projection aligner according to claim 6, wherein the source signal is a primary voltage of the supply voltage to the light source.

8. A projection aligner according to any one of the preceding claims, wherein the sensor(s) also monitor the distribution of light in the optical path between the light source and the wafer.

9. A projection aligner according to claim 8, having detection means for detecting the luminosity and distribution of light in the optical path on the basis of the output of the sensor(s).

10. A projection aligner according to claim 9, further including compensation means for changing the distribution of the light in the optical path on the basis of the output of the detection means.

11. A projection aligner according to claim 10, wherein the compensation means includes a plurality of light shield devices, each of light which has a light shield plate movable into the optical path to adjust the amount and/or distribution of light in the ptical path.

12. A projection aligner according to any one of claims 9 to 11, having an alarm triggered by the detection means when the light distribution or

intensity deviates from a predetermined distribution or intensity.

13. A projection aligner substantially as herein described, with reference to and as illustrated in Figures 1 and 2, or Figures 3 to 5, or Figure 6 of the accompanying drawings.

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